

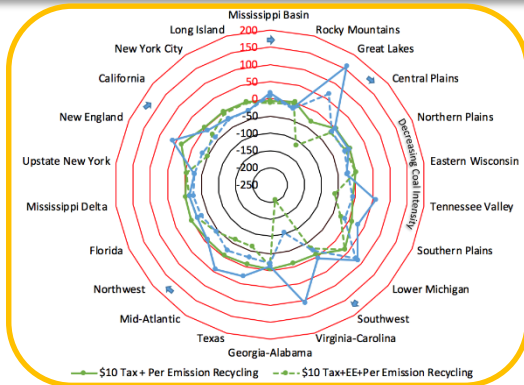
Enabling the Great Energy Transition: Technology and Policy Challenges & Opportunities

Dr. Marilyn A. Brown

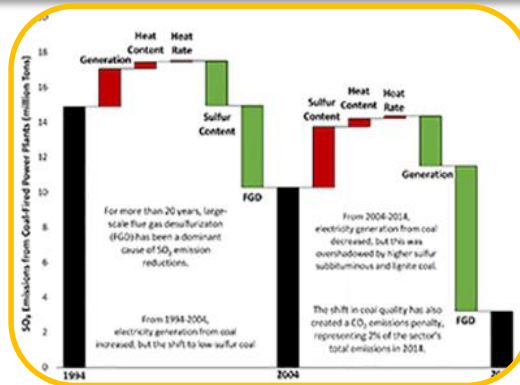
Regents & Brook Byers Professor of Sustainable Systems
Georgia Institute of Technology

September 5, 2018

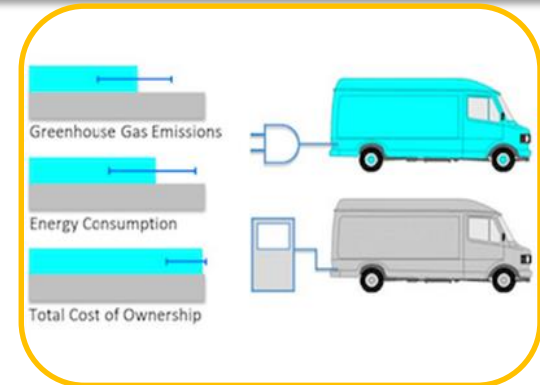
Georgia Tech's Climate and Energy Policy Lab



Carbon Tax: Winners & Losers (\$/capita)



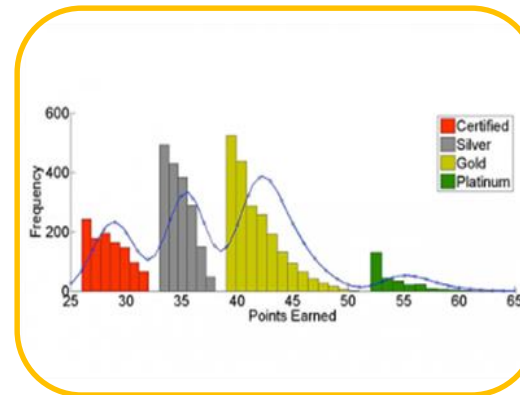
U.S. SO₂ Emissions: Shifting Factors



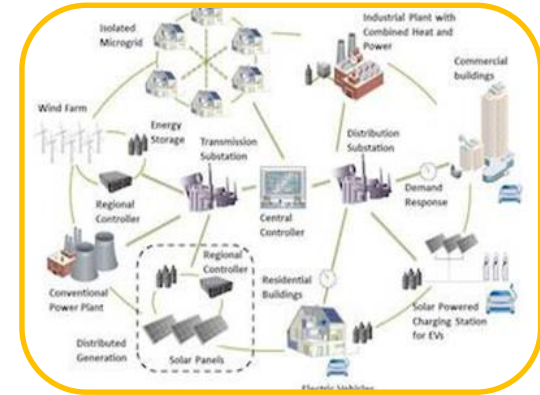
Electric Urban Delivery Trucks



Climate and Energy Laboratory Faculty



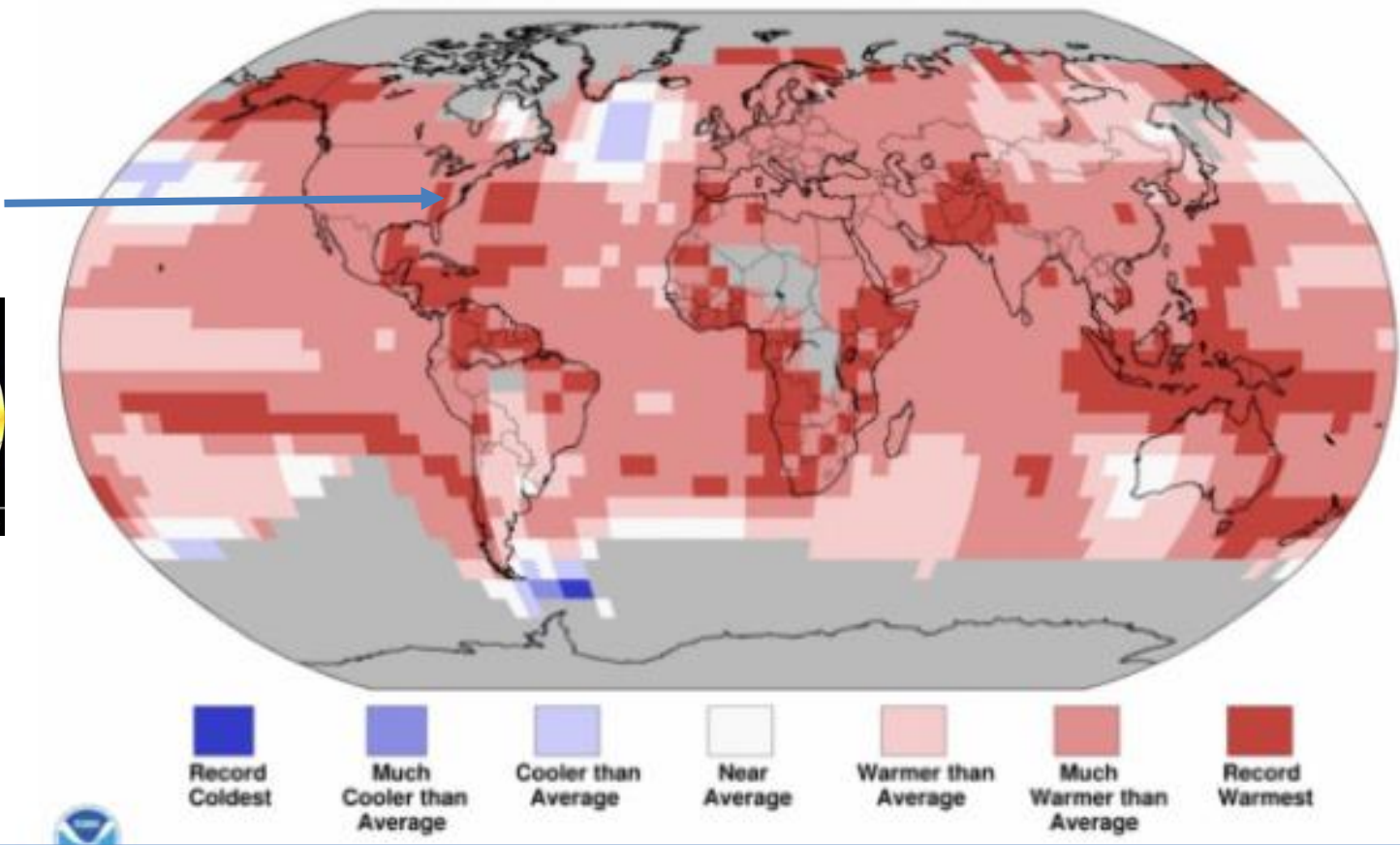
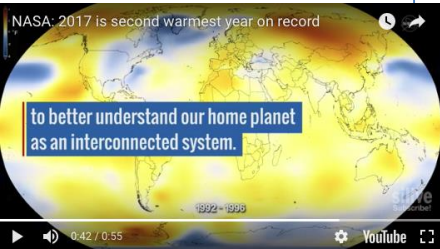
Point Distribution for New LEED Construction



The Emergence of Smart-Grid Policies

2016=Hottest Year on Record; 2017=2nd

The Southeast
Is no longer
“near average”



http://www.silive.com/news/2018/01/2017_second_warmest_year_on_re.html

2016 temperatures compared to normal around the globe (NOAA)

NCA4 Climate Science Special Report (2017): “it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century”

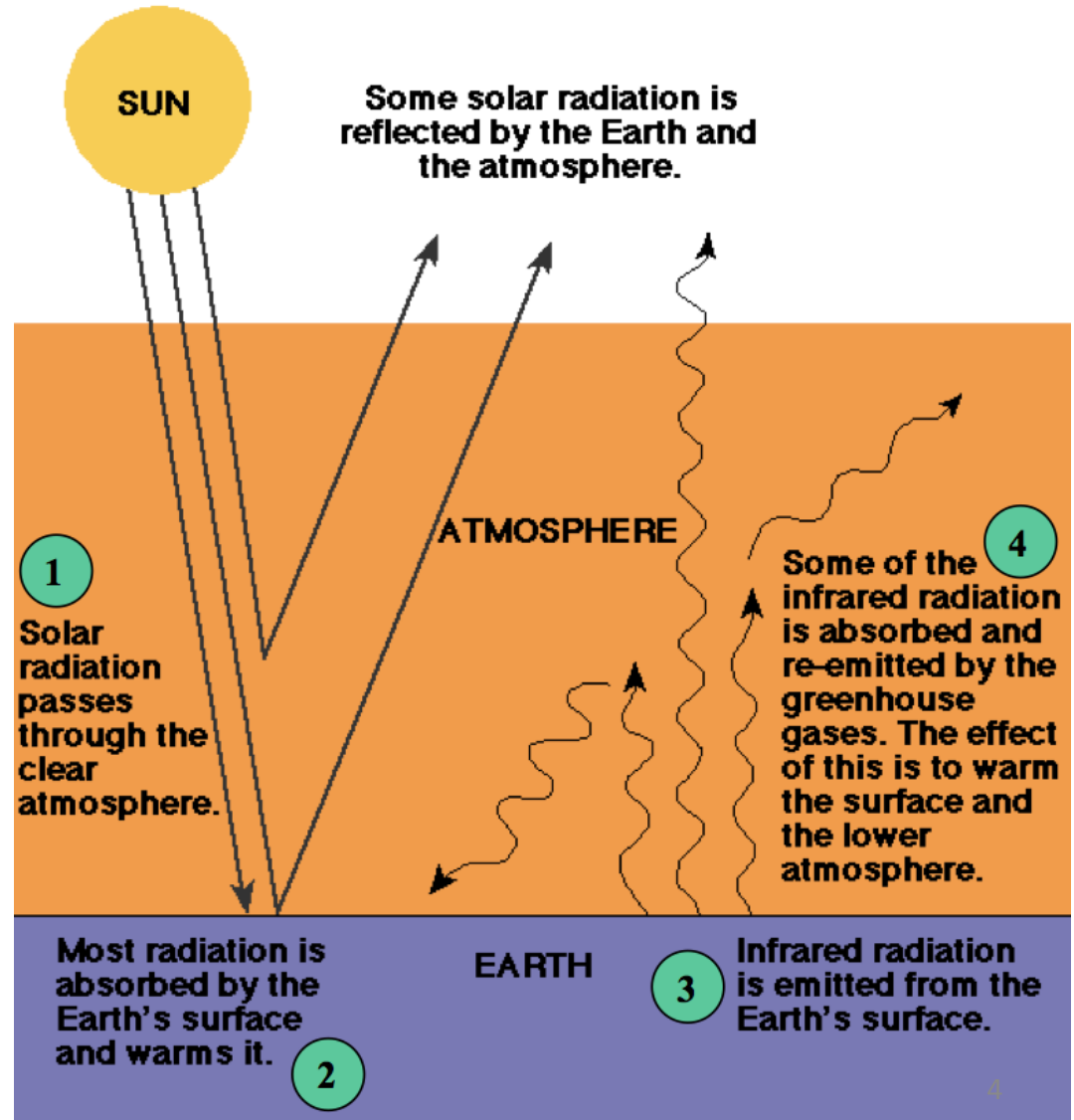
The “Enhanced” Greenhouse Effect

Greenhouse gases trap heat at the earth’s surface and prevent it from escaping.

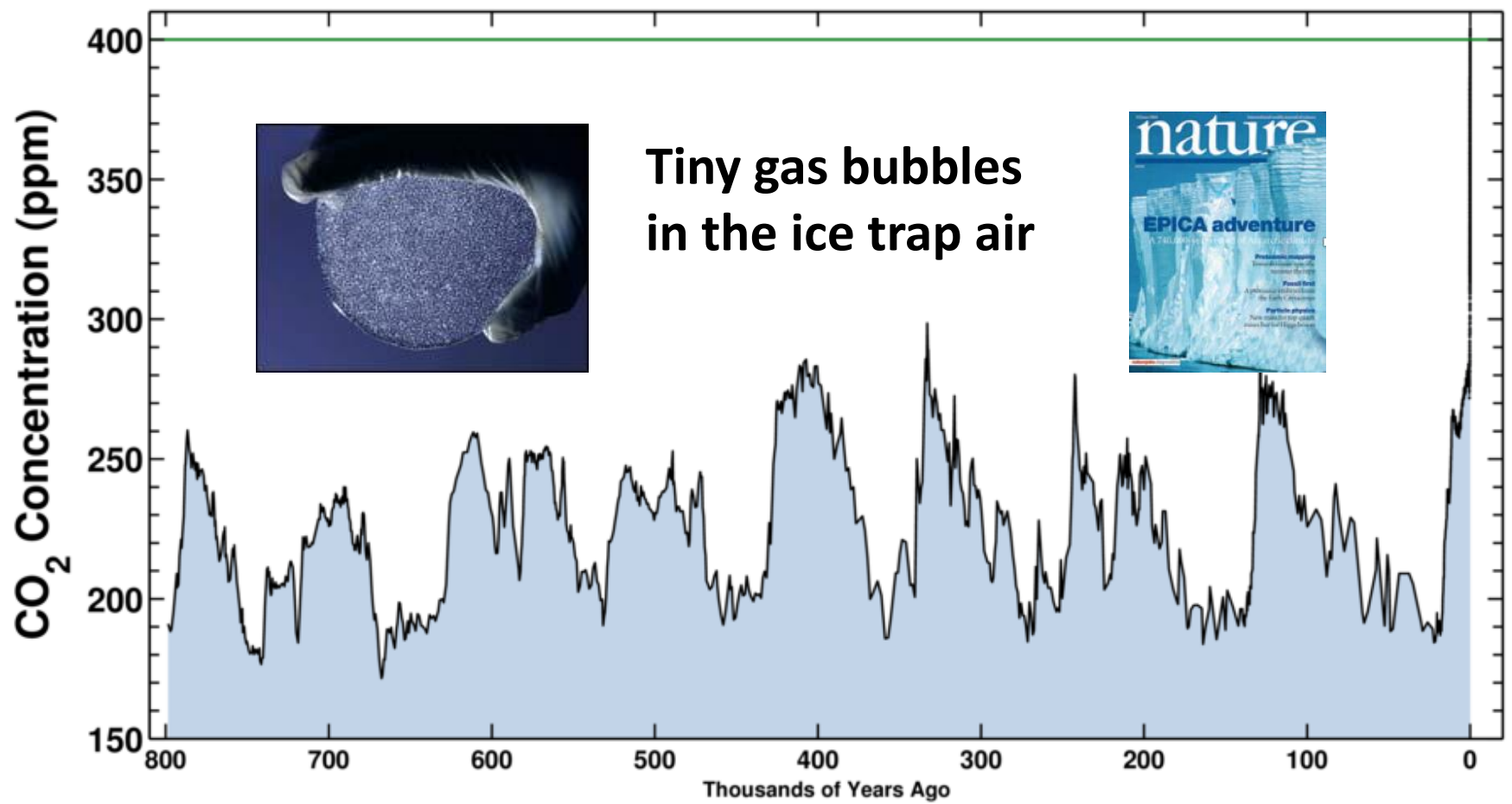
The most abundant GHGs are naturally occurring:

- water vapor (H_2O)
- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)....

Human actions are “enhancing” this natural greenhouse effect-- primarily from the burning of fossil fuels.



CO₂ Concentrations Over 800,000 Years Shows Today's



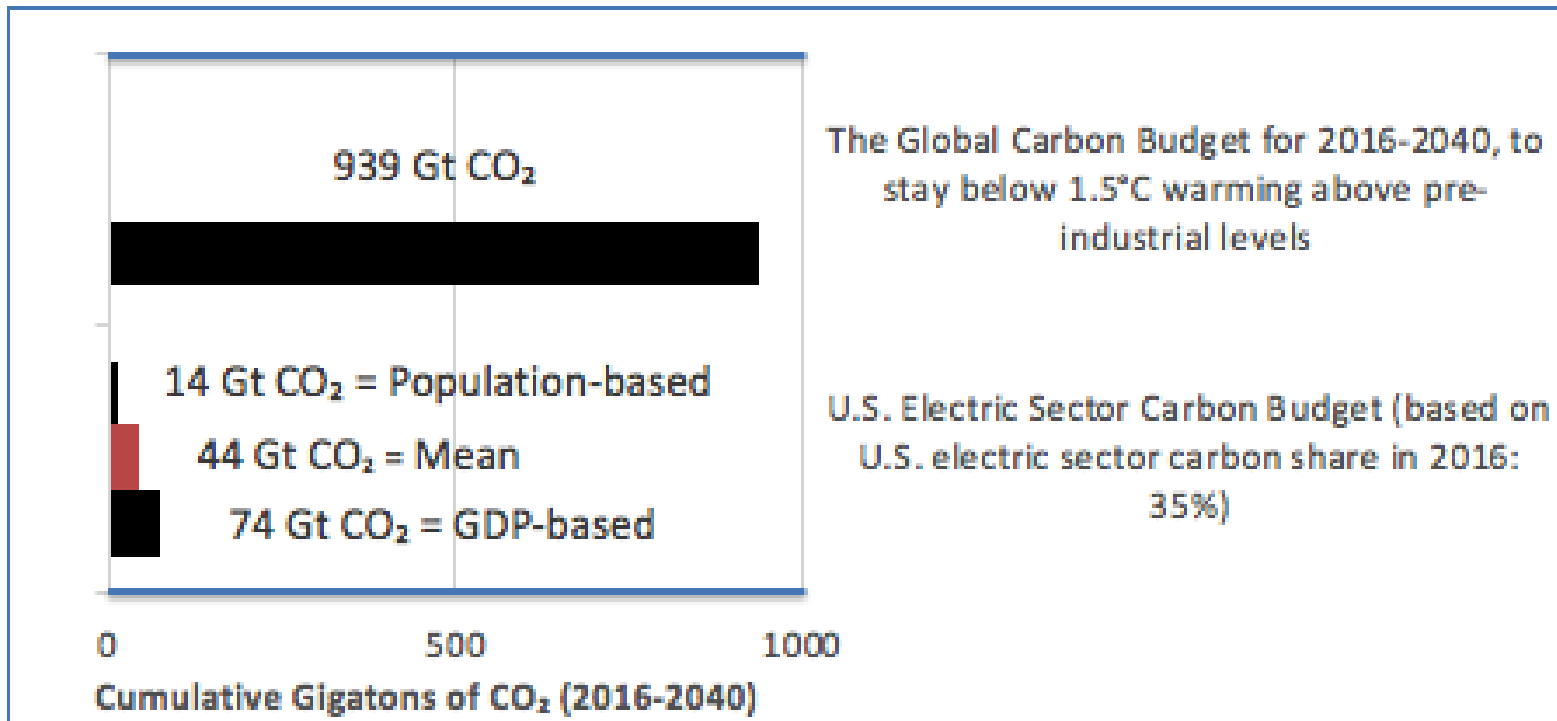
Deep Decarbonization

- The Paris agreement calls for “pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels”.
- But few have studied mitigation pathways consistent with such deep carbon reductions.



What is 1.5°C Budget for the U.S. Electricity Sector?

Equally weighting global “equity” and “inertia”, a 25-year carbon budget for the U.S. electric sector = **44 Gt CO₂**.

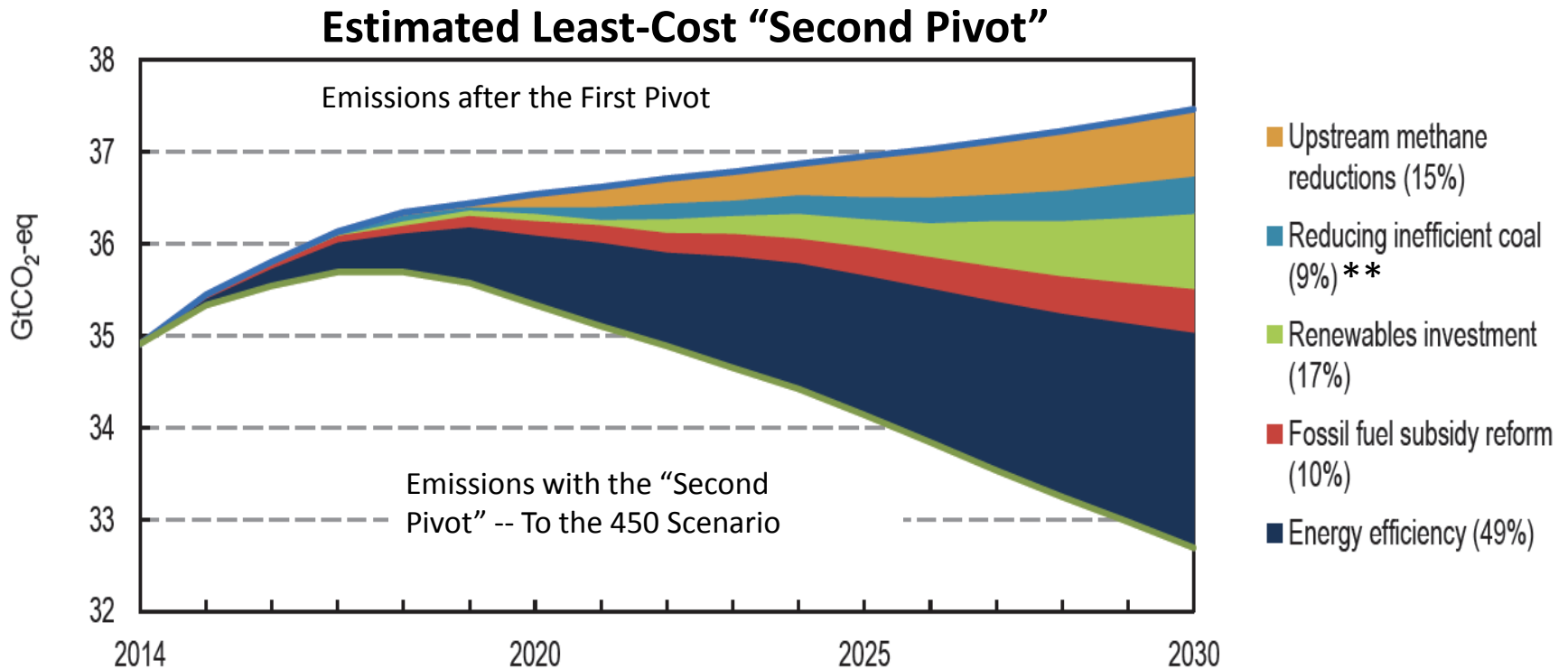


Source: Brown, Marilyn A. and Yufei Li. 2018. “Carbon Pricing and Energy Efficiency: Pathways to Deep Decarbonization of the U.S. Electric Sector,” *Energy Efficiency*.

After the Paris Accord “Pivot,” What Comes Next?

The International Energy Agency, Intergovernmental Panel on Climate Change, and many others conclude that:

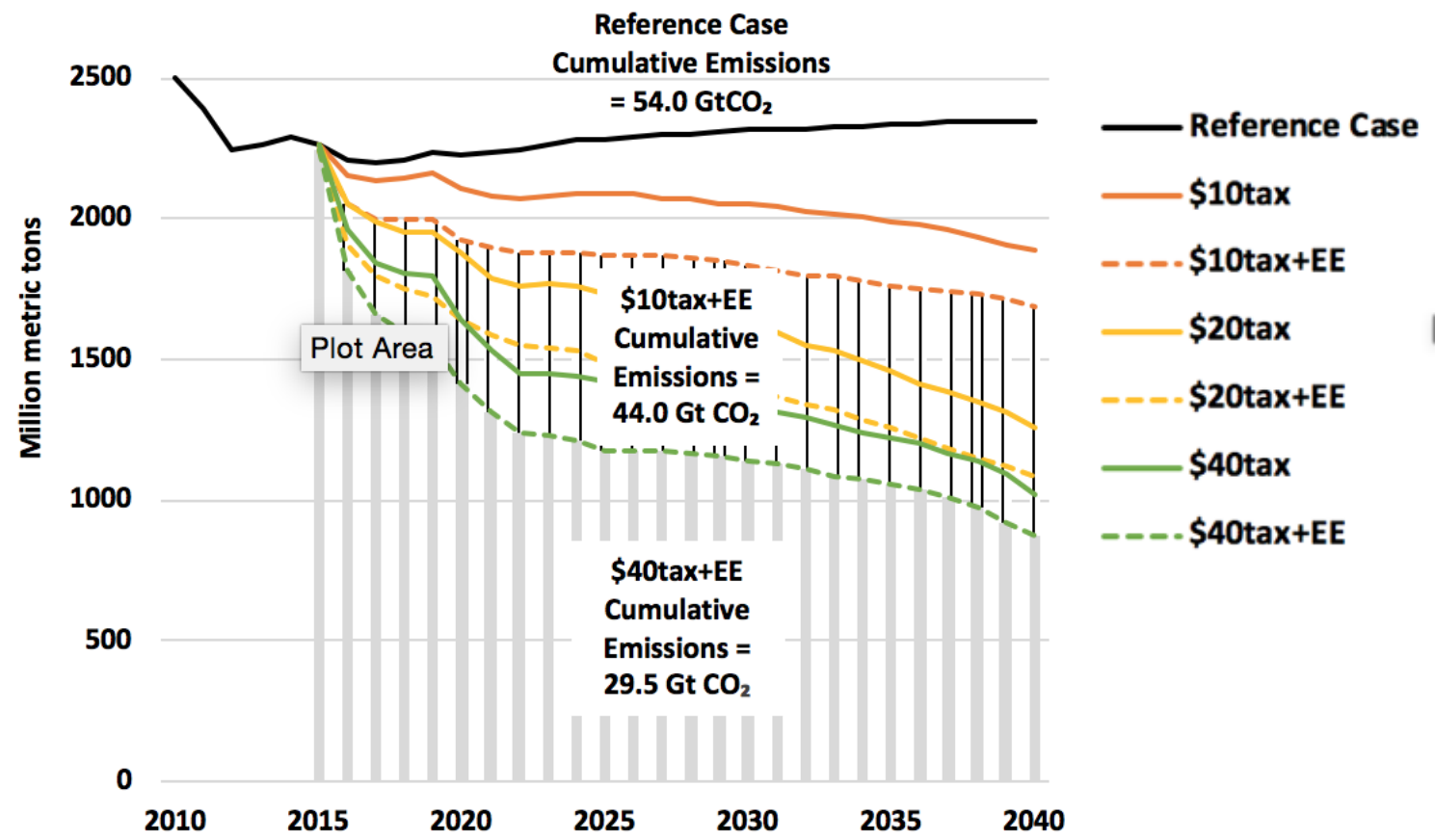
- the electricity sector offers the least-cost CO₂ reduction options



IEA (2015) *Energy and Climate Change: A Special Report*

Results: CO₂ Emissions from the U.S. Electric Sector Across Mitigation Scenarios

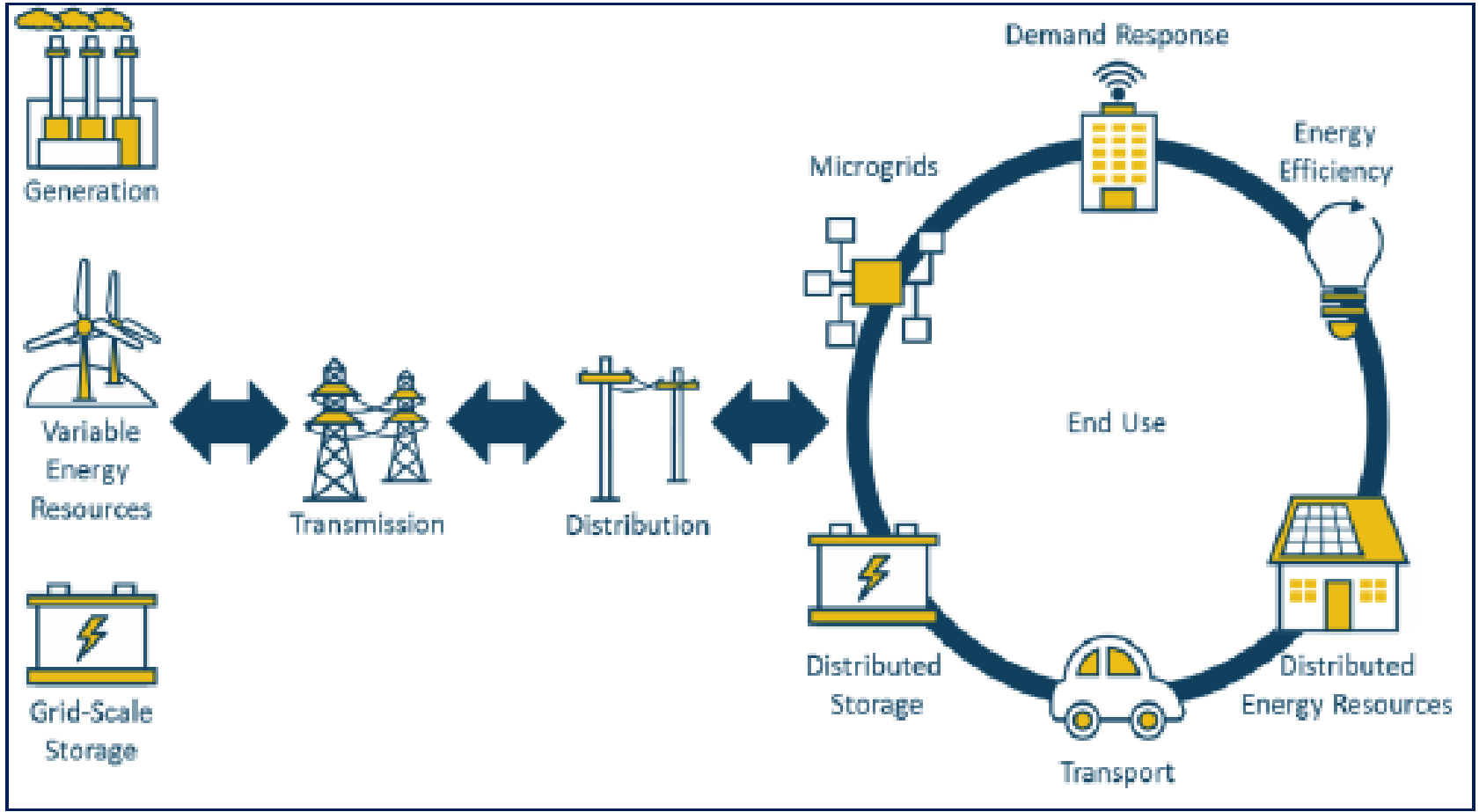
Current policies would lead to 54 GT CO₂ in the U.S. electric sector from 2016-2040



A \$10 tax/ton of CO₂ with strong energy efficiency could reduce this to 44 GT CO₂.

The Electricity Supply Chain is Changing

And the utility business model is beginning to change, too.



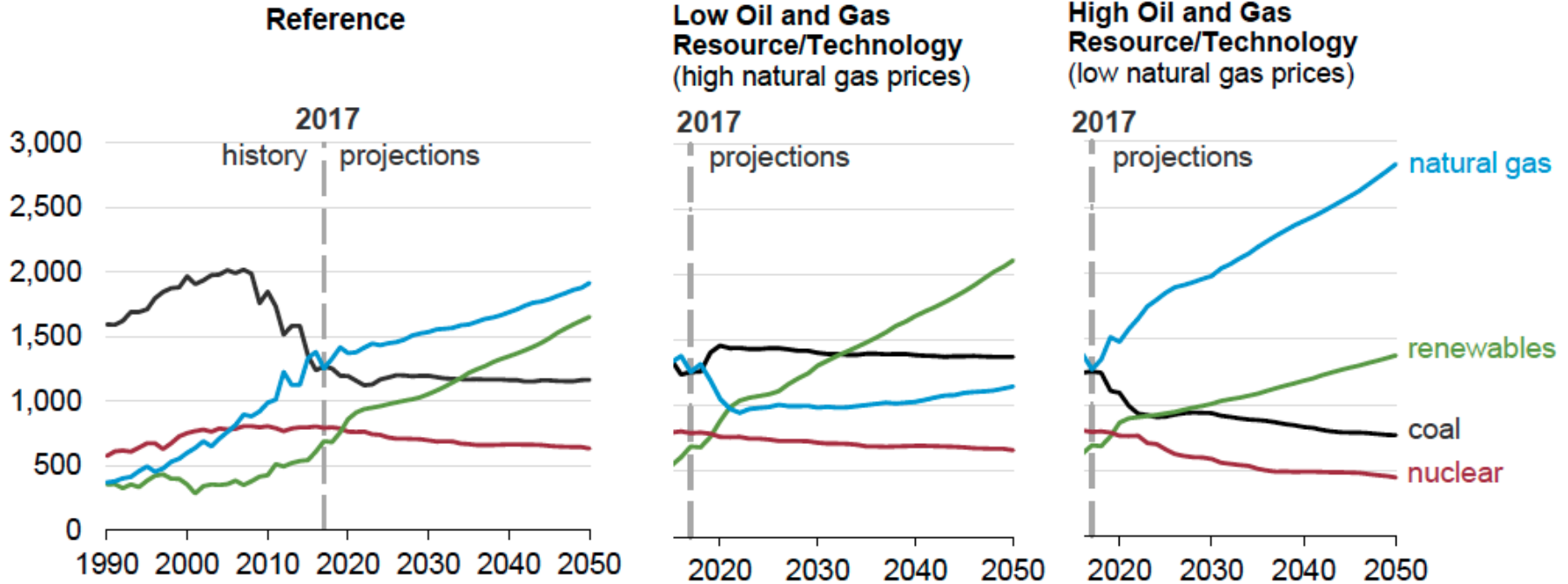
Source: DOE. 2017. Quadrennial Energy Review: Transforming the Nation's Electricity System, Figure S-3

Electricity Resources are Becoming More Distributed

- >14 million electric customers are supplying power back into the grid.
- Distributed solar capacity is now nearly 1% of total U.S. generating capacity (14 GW).
- >80 GW of combined heat and power now accounts for ~8% of total U.S. generating capacity.
- >16 million customers participate in wholesale or utility demand response or time-varying rate programs.
- The charging cycles of 535,000 EVs are now being managed.

EIA Forecasts that Natural Gas will Outcompete DERs

Electricity generation from selected fuels
 billion kilowatthours

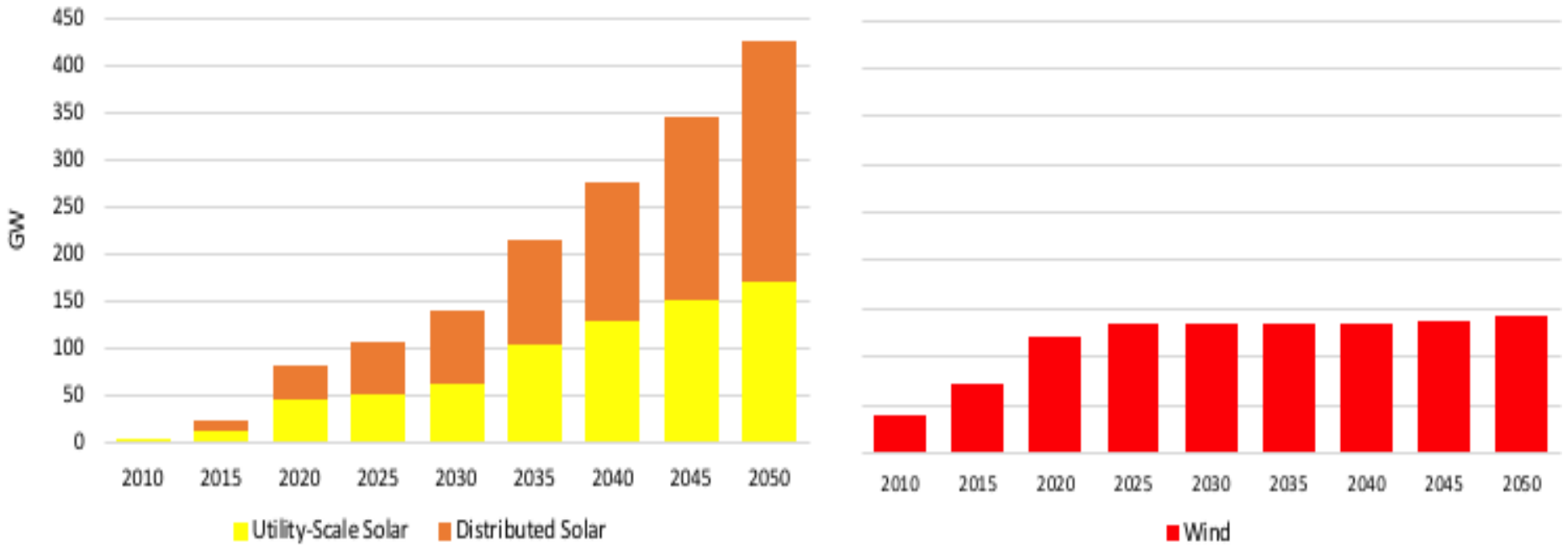


- But supply-side energy forecasts are wide-ranging.*
- Demand growth forecasts range more narrowly, from zero to 20%.

*See: "The Next Financial Crisis Lurks Underground Fueled by Debt and Years of Easy Credit."
 By Bethany McLean NYTimes, Sept. 1, 2018

Solar is Forecast to Eclipse Wind

And distributed solar surpasses utility-scale solar.
 What policies are needed for peer-to-peer exchanges?

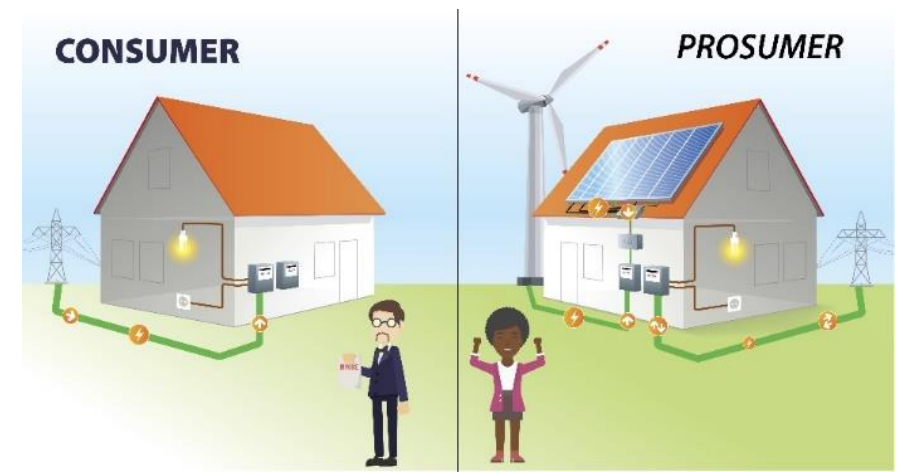


Utility-scale and distributed solar and wind capacity (gigawatts)

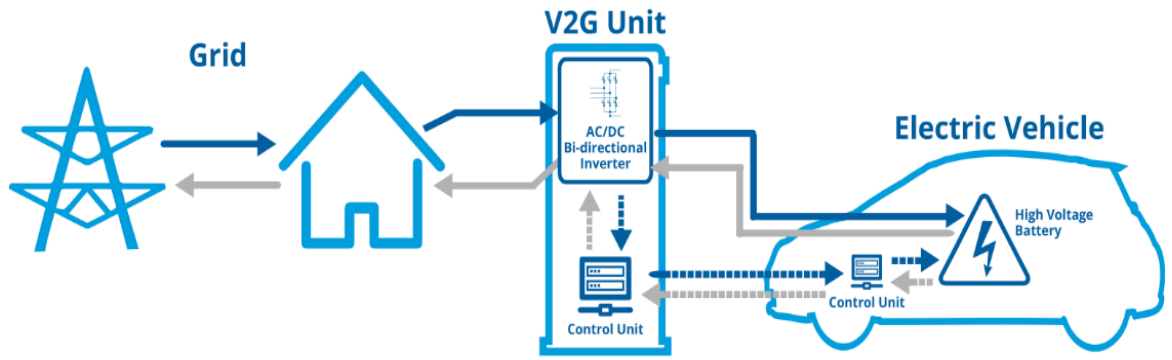
Source: Energy Information Administration. 2018. *Annual Energy Outlook 2018*, On-Line Data.
 **You have to go “on-line” to get the full EIA solar forecast

The Creation of “Prosumers” and the “Sharing Economy”

- Consumers are becoming producers – “Prosumers”
 - Facilitated by the falling cost of solar panels
 - Home battery systems are on the move
 - Many more EV models available and a growing charging infrastructure



Grid-integrated vehicles could become another form of “prosumerism”





Smart meters provide two-way communication:

- ✓ Powerful when combined with real-time electricity pricing
- ✓ WiFi enabled; controlled from computers & cell phones
- ✓ Interfaced with in-home, in-office, and smart phone displays

Sensors for temperature, humidity, motion, and light eliminate wasted energy (and improve comfort).

Thermostats that Learn



How Secure are Smart Homes?

70M smart meters were installed in US by end of 2016

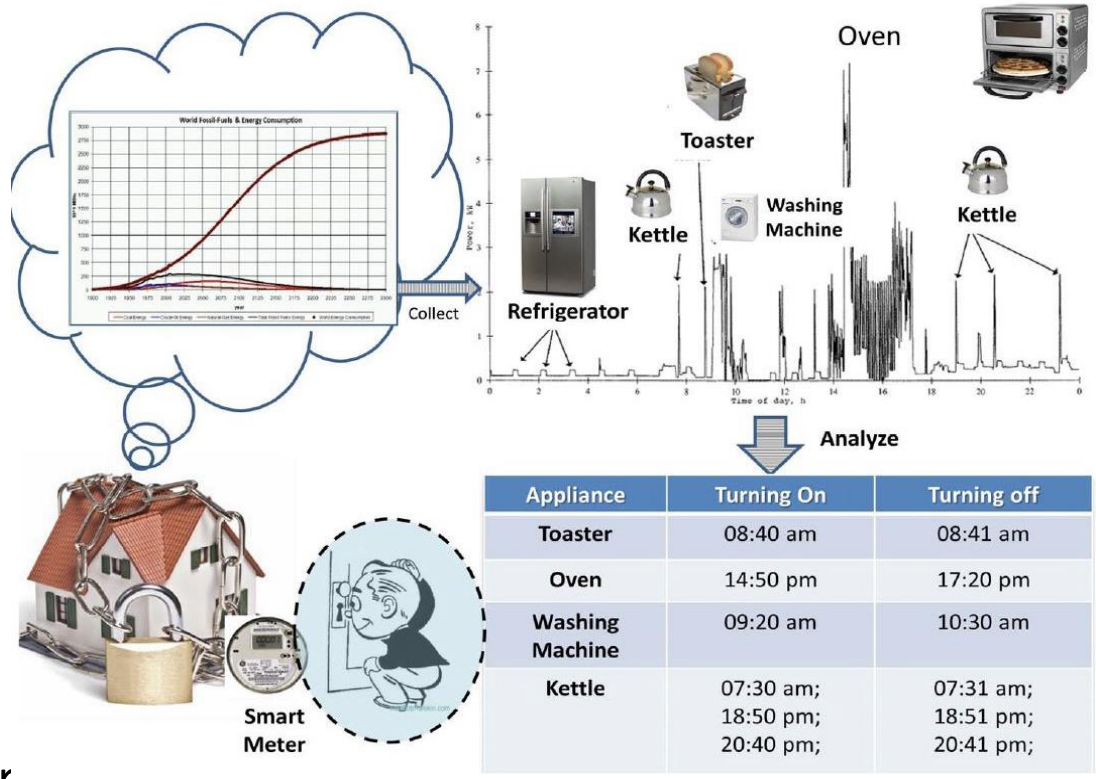
17.7B IoT connected devices were installed in U.S. by end of 2016



Smart thermostat, smart dishwasher, smart light bulbs, speaker, refrigerator, TV,...

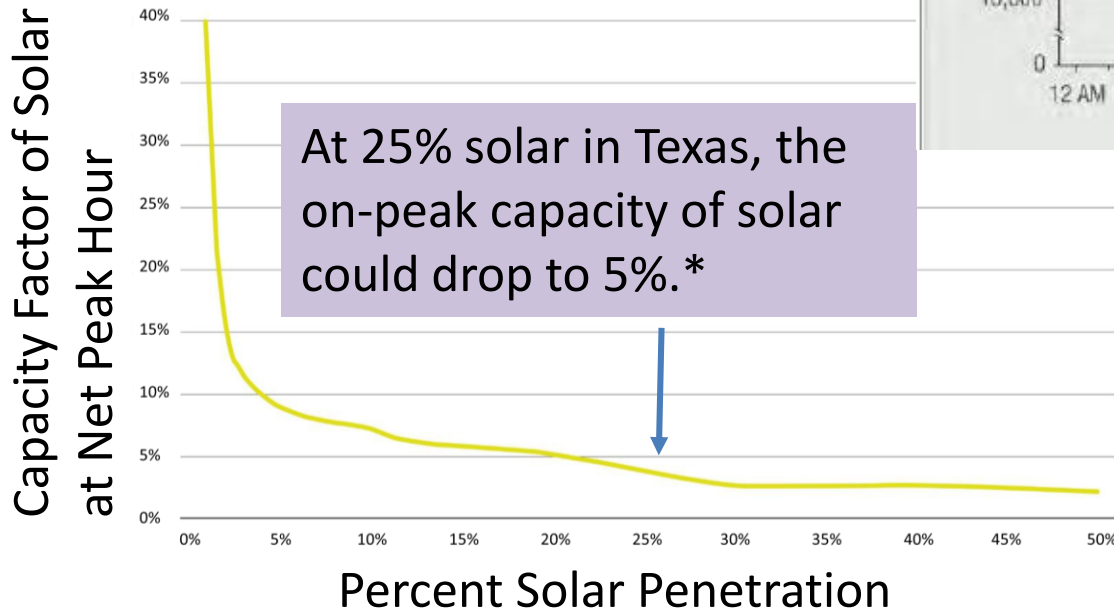
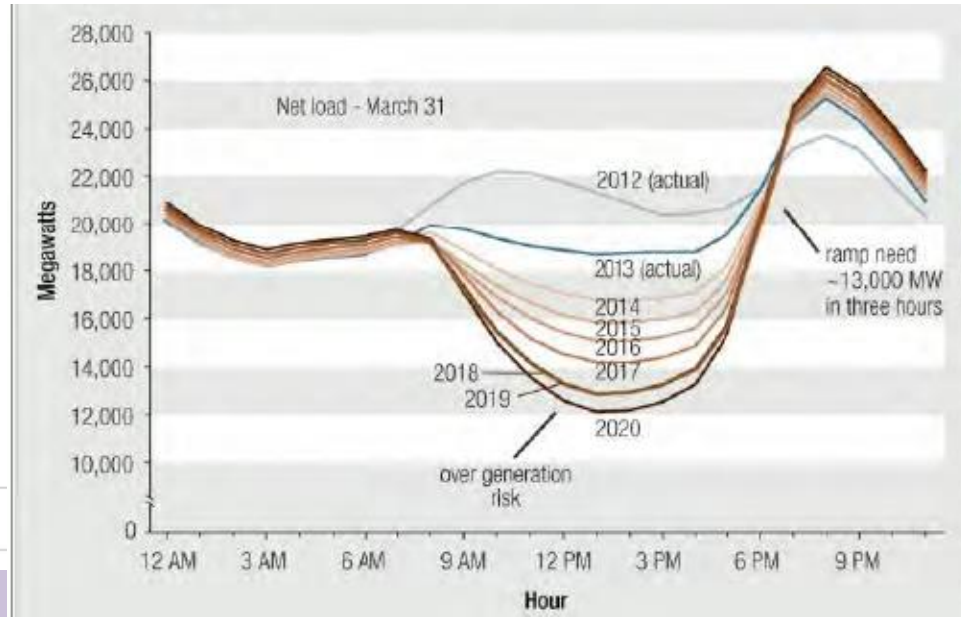
Is Data Privacy a Problem?

- Communications between smart appliances is often **wireless**—enabling eavesdroppers
- Eavesdropper can find user **signatures**:
 - Discern daily schedules of residents
 - Identify the best times for a burglary
 - Detect the expensive appliances, alarm systems, or medical equipment



Managing Energy Resources in Real Time is Complicated

- Peak day loads are shifting
 - The California duck curve
 - Growing need for flexible generating capacity

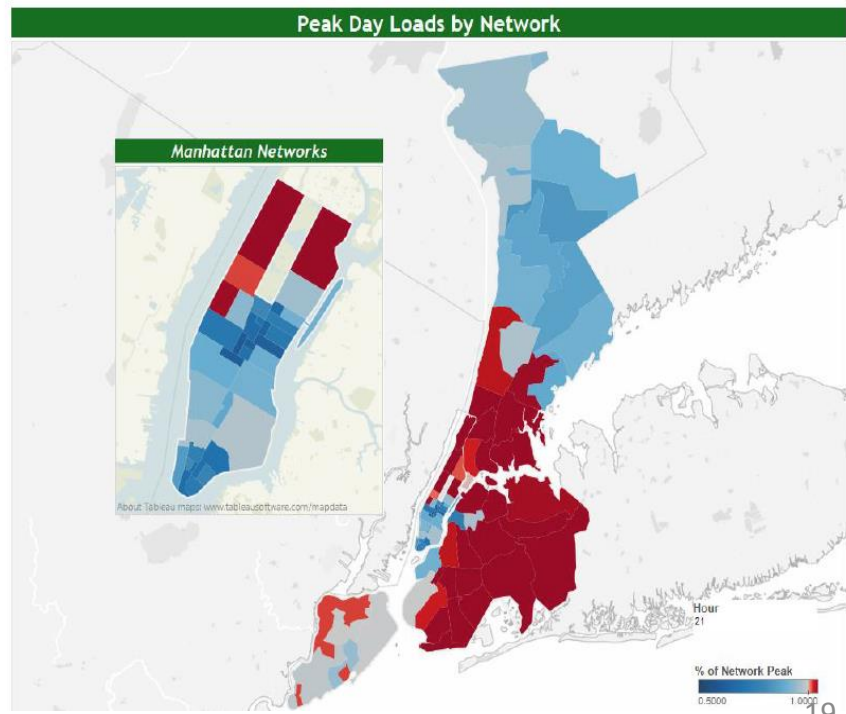
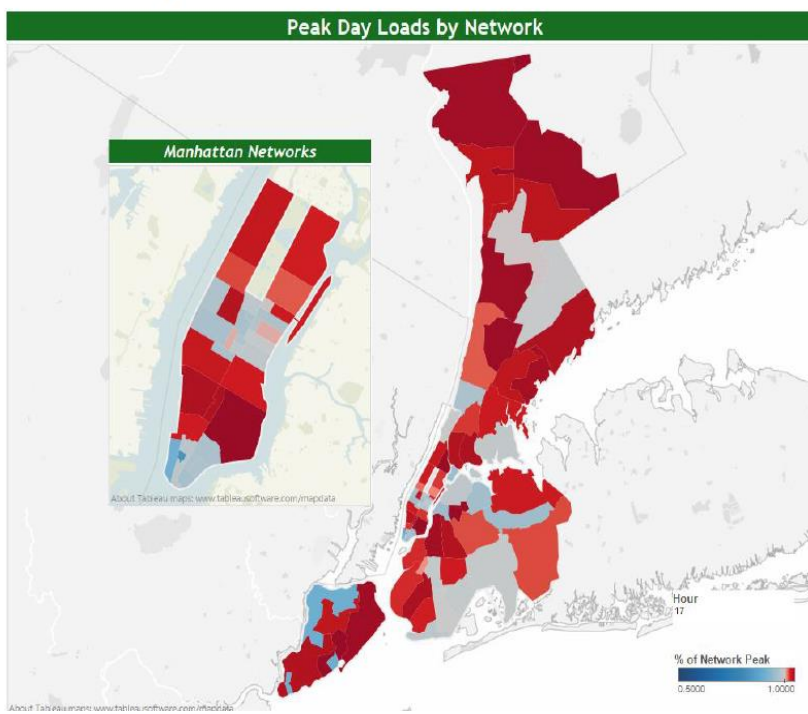


- Resources need to be managed in real time

*Source: DOE. 2017. *Staff Report to the Secretary on Electricity Markets and Reliability*¹⁸

Geospatially Managing Demand

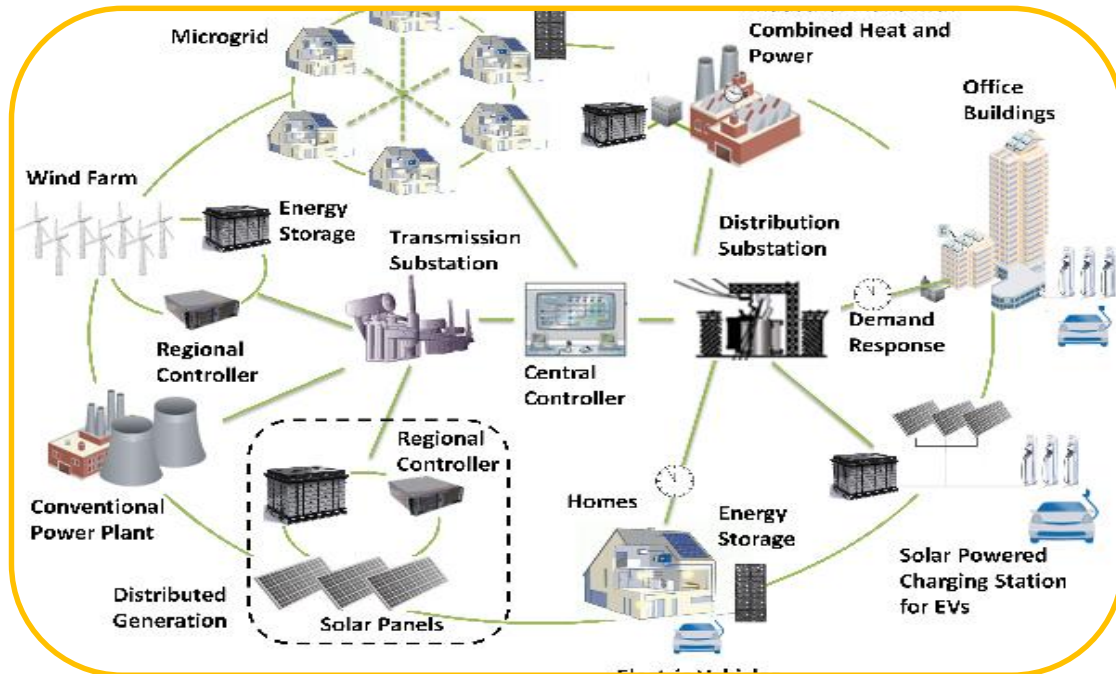
- Resources need to be deployed into specific zones:
 - The duck is walking in New York City
 - Result = ConEd's Brooklyn Queens Demand Management Program



Transportation & Electricity: A Beneficial Merger

More renewable electricity + more electric vehicles: “complementary” trends:

- ✓ With renewables, EVs are even cleaner
- ✓ With EVs, the grid can be better balanced



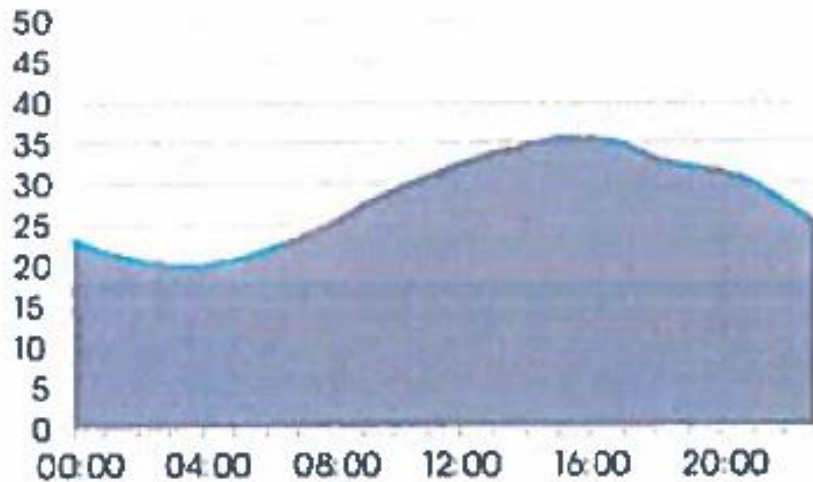
Brown, Marilyn A., Shan Zhou, and Majid Ahmadi. 2018. "Governance of the Smart Grid: An international review of evolving policy issues and innovations," *Wiley Interdisciplinary Reviews (WIREs): Energy and Environment*.

The Wild Card: Electric Vehicles

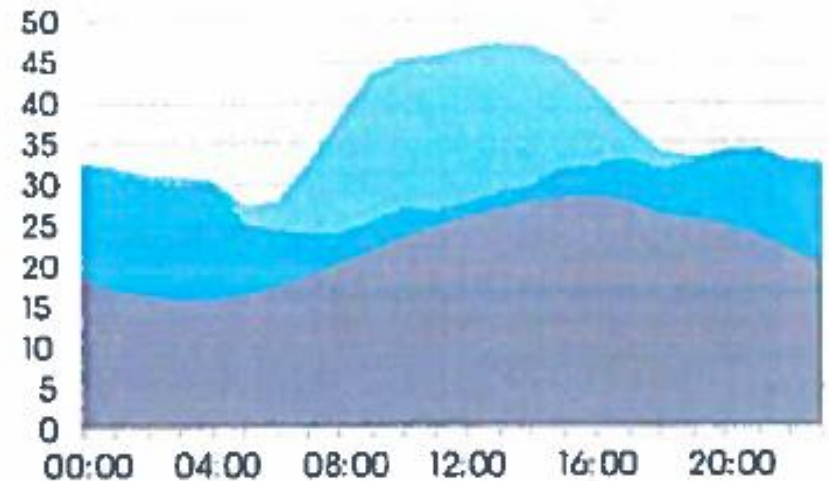
Market share of new electric, plug-in hybrids, and hybrid vehicles grow from **4%** in 2017 to **19%** in 2050 in the EIA 2018 Reference case; **100%** in DNV-GL 2018 forecast.

The impact on load curves could be transformational....

GWh California – Typical Summer Day, 2017



GWh California – Typical Summer Day, 2050



General
 EV demand (fixed)
 EV demand (dynamic)

Source: Source: Bloomberg New Energy Finance. 2018

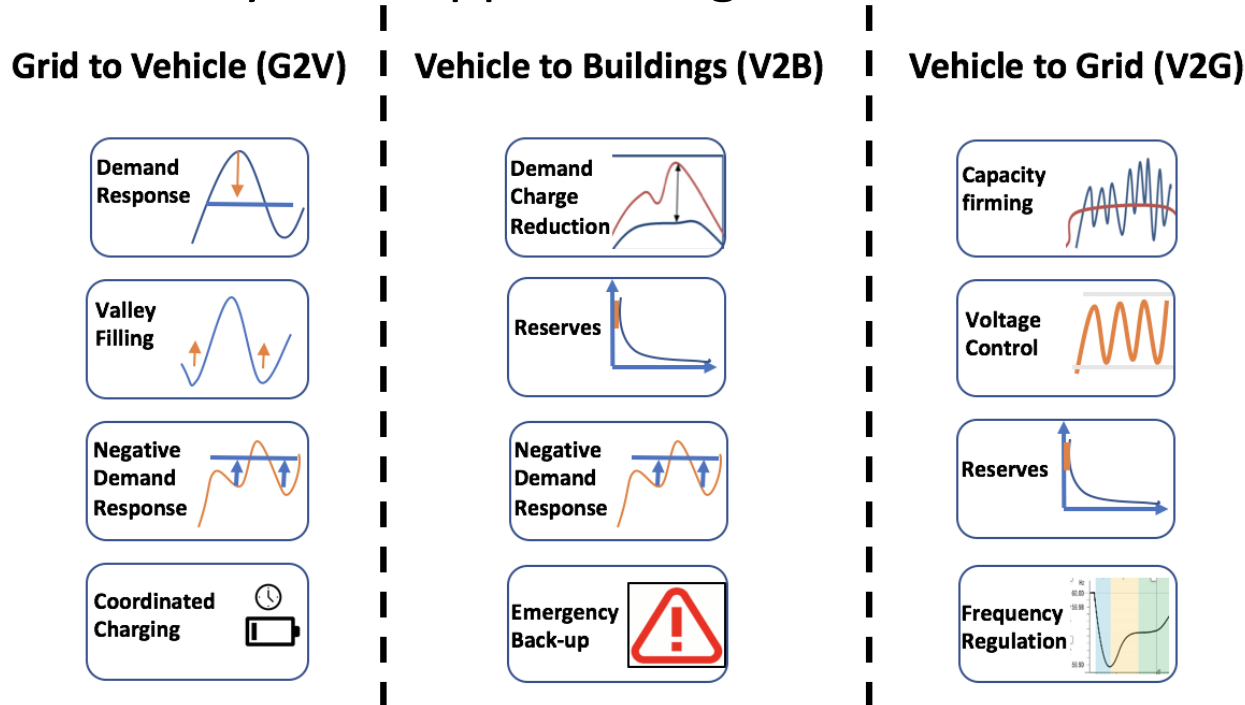
Residential storage faces sunny prospects this year

Pairing storage with rooftop solar could boom if interest translates into action.



What Roles Could EVs Play?

- They would reduce GHG emissions compared to ICEs.
- But also, they can support the grid.

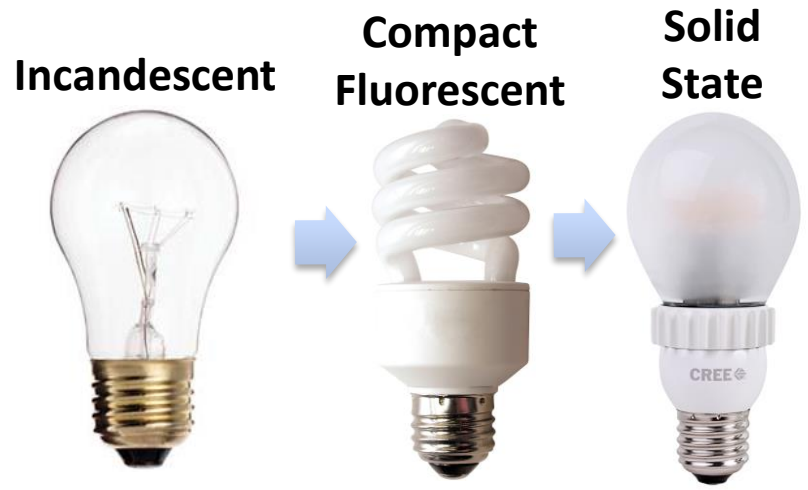
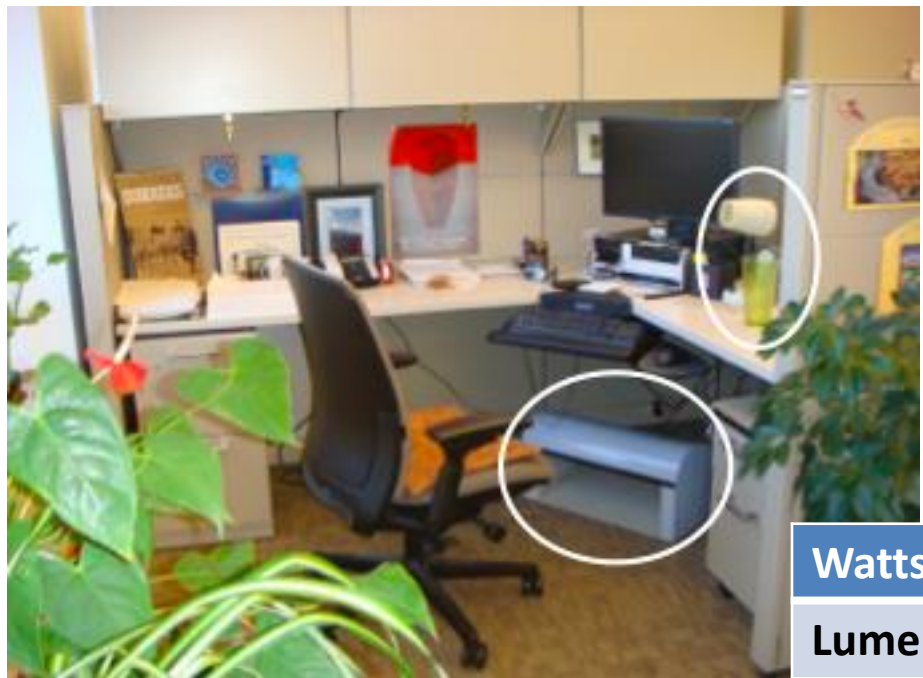


- How much are these grid services worth?
- What business models can be used to create value?

Don't Forget Energy Efficiency & Demand Response

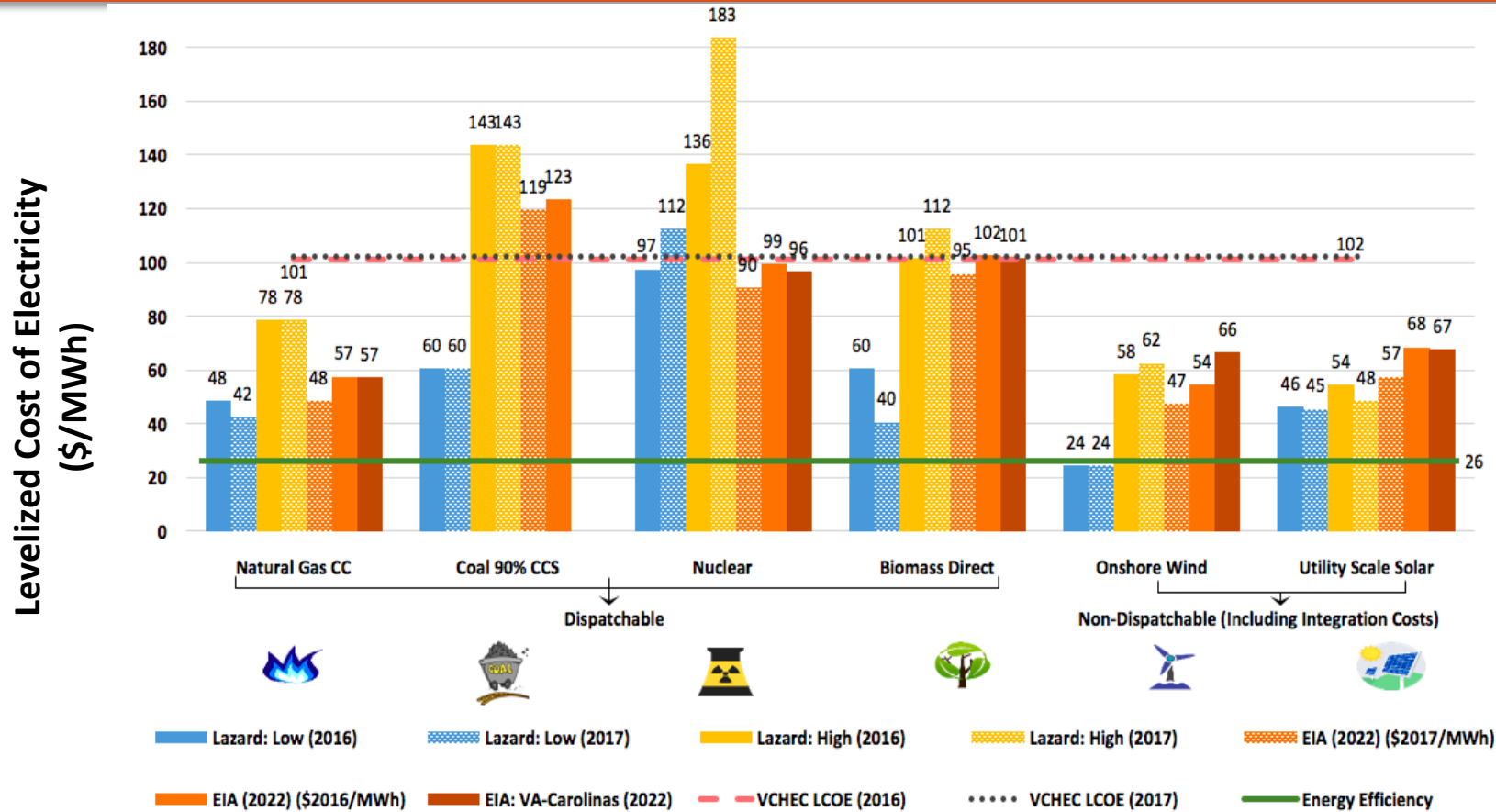
- **Energy Efficiency Improvement** – Increasing the services provided per unit of energy consumed.

Avoiding the ubiquitous use of fully lit and conditioned spaces



	Incandescent	Compact Fluorescent	Solid State
Watts	60	14	11
Lumens per Watt	14	64	84

Energy Efficiency is the Least Cost Energy Resource



According to Lazard & EIA, new natural gas, wind and solar are competitive (not biomass, coal, or nuclear). According to LBNL, energy efficiency is the least-cost resource.

Conclusions

- The clean energy transformation has begun.
- A great deal is at stake, and delay is costly.
- More research is needed to develop smart technology and policy solutions—the regulatory “compact” may need to be overhauled.

For More Information

27

<https://cepl.gatech.edu/sites/default/files/attachments/Pottsdam%206-14-18.pdf>

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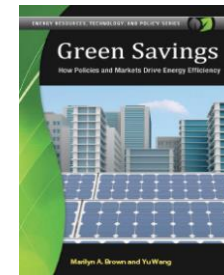
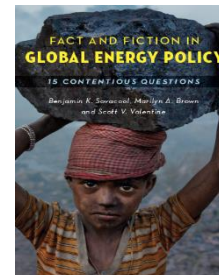
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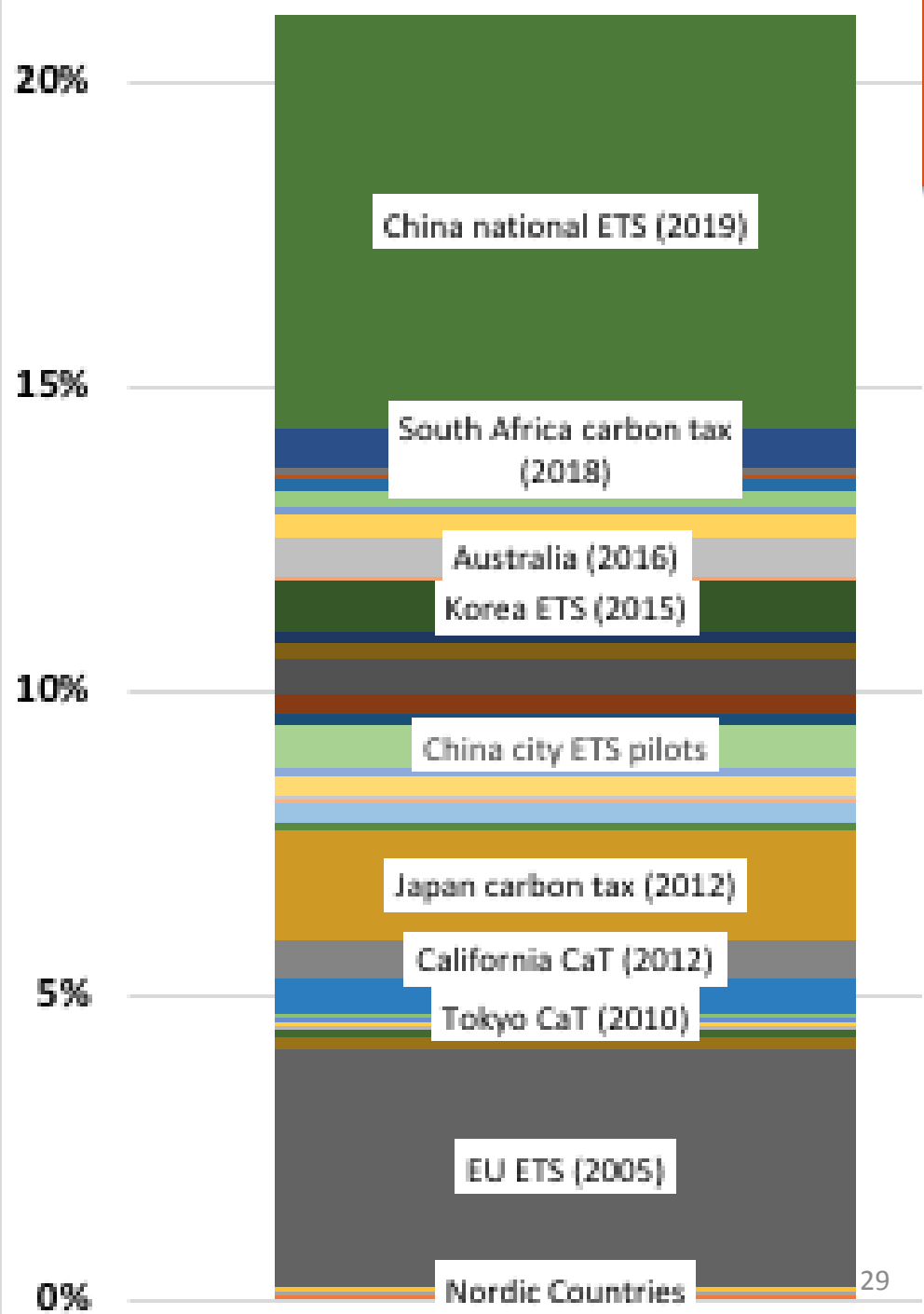
Climate and Energy Policy Lab:

www.cepl.gatech.edu



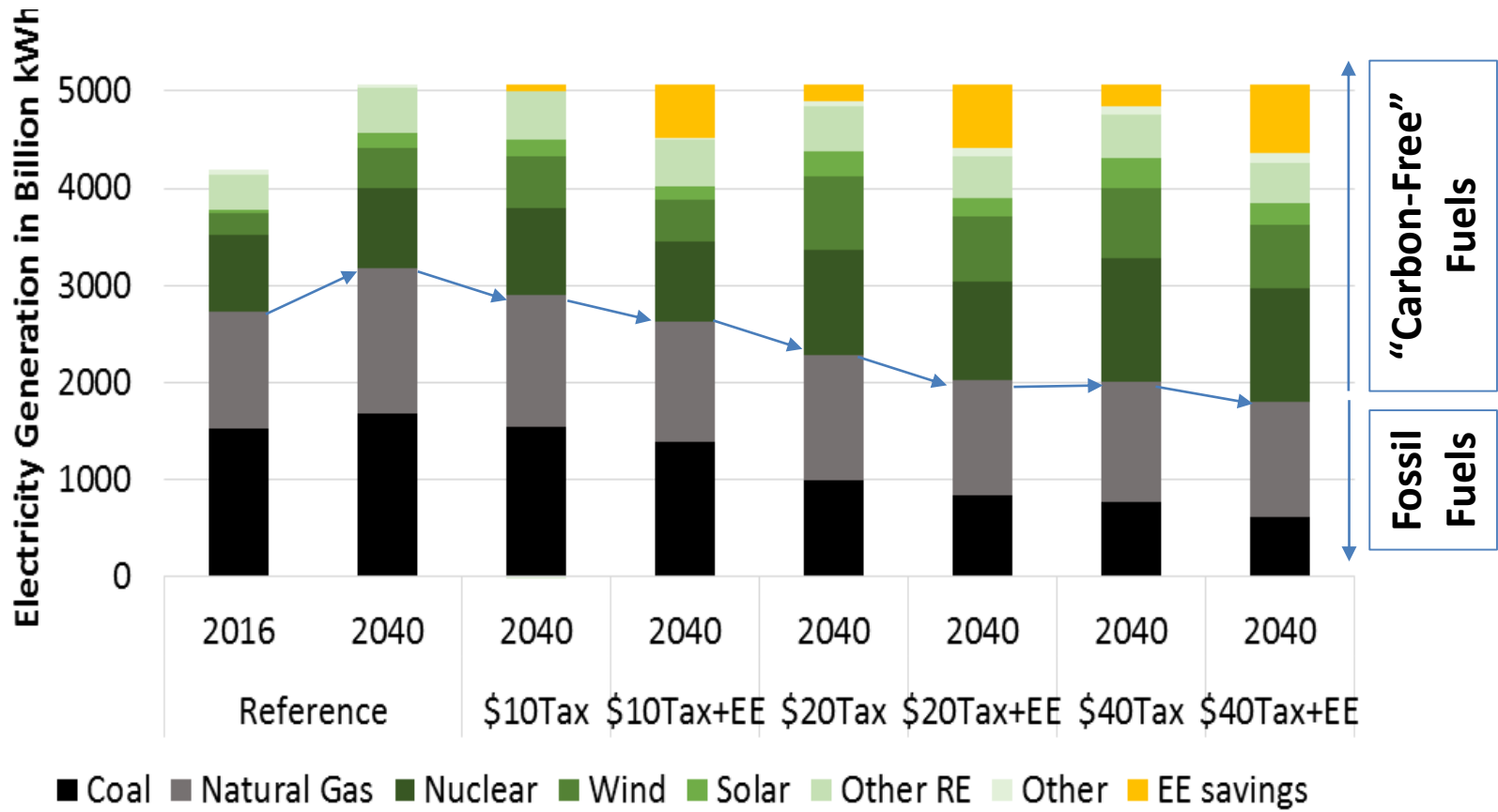
EXTRAS

Carbon Pricing Schemes Cover 22% of Global CO₂ Emissions



Consider Carbon Taxes on the U.S. Electric Sector Fuel Mix

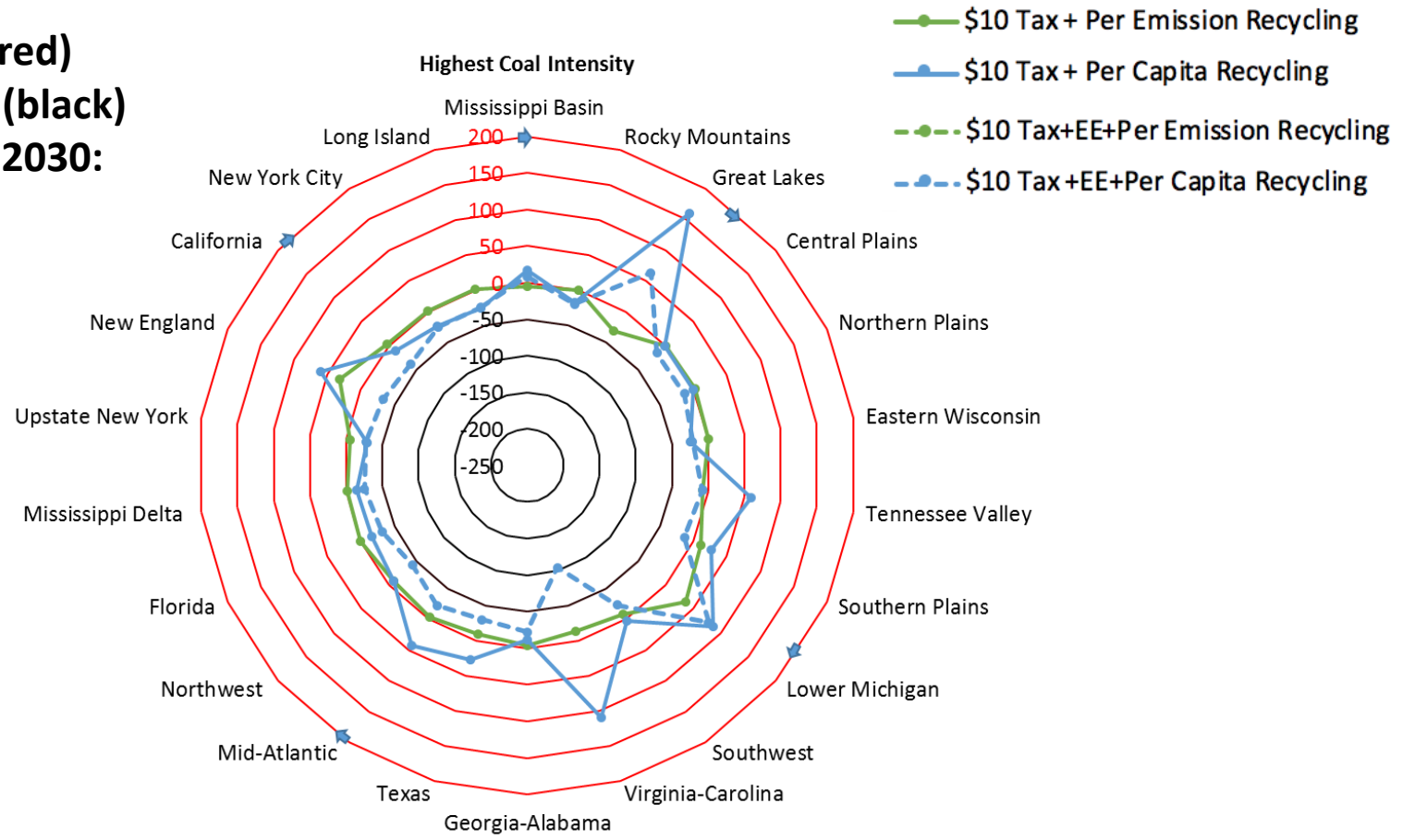
- Taxes of \$10, \$20, and \$40 per metric ton of CO₂ (in \$2013) in 2020 would shrink emissions



- To offset this decline, nuclear, wind, and solar would grow.
- Scenarios with strong energy-efficiency policies have even less fossil fuel generation.

Regional Winners and Losers of Carbon Pricing Schemes

Policy costs (red) and benefits (black) per capita in 2030:



Per capita recycling of tax revenues would result in a transfer of wealth from the South and Central states to the Northeast and Western states.

Source: Brown, Marilyn A. and Yufei Li. 2018. "Carbon Pricing and Energy Efficiency: Pathways to Deep Decarbonization of the U.S. Electric Sector," *Energy Efficiency*.